DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS

THE

BULLETIN

OF THE

BEACH EROSION BOARD

OFFICE, CHIEF OF ENGINEERS
WASHINGTON, D.C.

VOL. 9 JANUARY 1, 1955 NO. 1

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A SIMPLIFIED METHOD OF DETERMINING DURATIONS AND FREQUENCIES OF WAVES GREATER OR LESS THAN A SPECIFIED HEIGHT

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In planning for many types of marine operations it becomes important to know the length of time over which, and frequency with which, waves greater or less than a specified height may be expected to occur. For example, a condition of 3-foot waves is about the maximum under which accurate hydrographic survey data may be obtained by small boats or DUKWS in the nearshore area, higher waves serving to mask out small depth changes indicated on an echo sounder record due to the resultant (up-and-down) motion of the vessel. A 3-foot wave height is also regarded as being roughly the upper limit for some types of geophysical survey operations, and it is the critical height for operation of one type of barge used for transporting crude oil ashore from offshore wells. Accurate knowledge of the frequency of occurrence of waves above or below these limiting heights is then of considerable importance in determining the economic feasibility of operating in an area, in choosing between operation in one area or another, in selecting the most suitable time for carrying out such operations, and in overall planning of the operation (particularly as regards probable amount of lost time).

Frequency diagrams of occurrence of various wave heights are needed for design of structures subject to wave action, and are frequently obtained by hindcasting from weather maps. However, it is generally only the higher waves that are of interest, those above, say, 8 or 10 feet. The lower waves, however, account for a much greater percentage of the time involved, and methods of forecasting which would automatically eliminate thorough consideration of these waves would result in much more rapid and economical determination of design criteria.

In such cases as these the wave height is of interest only as it is of greater or less magnitude than a particular value; i.e. the actual wave height is not of importance. There would seem to be, therefore, nothing particular to be gained in forecasting the actual height rather than just whether or not the wave is over the limiting value.

This can be done much more simply than by making a complete forecast of the actual height, as curves showing the values of wind velocity and duration, and fetch length and decay necessary to produce waves of a particular specified height may be drawn rather easily from the revised Sverdrup-Munk curves presented by Bretschneider*. If the particular

*Bretschneider, C. L. - Revised Wave Forecasting Relationships, Proc. of the Second Conf. on Coastal Eng'g., Council on Wave Research, Eng'g. Foundation, 1952.

meteorological conditions considered result in a point lying below the appropriate curve, then the wave height will not be expected to reach the limiting value (or height of interest); similarly if the weather conditions result in a point on or above the appropriate curve, waves greater than the specified values may be expected to occur (and the unanswered question, as to whether the waves exceed the limiting value by 1 foot or by 50, is not important to the determination).

A set of curves showing limiting values for generation of 3-foot waves is shown in Figure 1, The curves show values of wind velocity and duration, and fetch and decay lengths necessary to produce the limiting waves of 3 feet. They are used in exactly the same manner as the usual generation curves used in wave forecasting, only instead of reading off the height of the generated waves, the decay distance resulting in the specified limiting wave height (3 feet) is obtained. If the actual decay is less than this value, then the waves will be greater than the (3-foot) limiting value; and if it is more, then the wave height will be less than the (3-foot) limiting value. For example, from Figure 1, with a wind speed of 20 knots, a duration of 12 hours, a fetch of 175 miles, and a decay of 350 miles it is seen that the wave growth is limited by duration, and that the waves will be reduced to 3 feet after a decay of about 200 miles; since the actual decay distance is 350 miles, the waves there will be expected to be less than 3 feet. If now the duration in this example had been 24 hours rather than 12, the wave generation would be limited by the 175-mile fetch length, and (from the figure) the waves would reduce to 3 feet after a decay of 500 miles; since the actual decay was only 350 miles, the waves there would be expected to be greater than 3 feet.

Although curves are shown for a 3-foot wave height only, it is a relatively simple matter to obtain them for any desired height. The method is shown below for the case of the 3-foot height, and a 100-mile fetch and 500-mile decay. Using the Bretschneider decay curves it may be seen that for a 500-mile decay with a minimum fetch of 100 miles, the relative decrease in wave height over the decay distance (H_D/H_F) may range between 0.26 and 0.33; this means that the wave height at the end of the fetch (H_F) which will produce 3-foot waves after the 500-mile decay must be between 9.1 and 11.5 feet (these values being obtained by dividing the H_D of 3 feet by the ratio H_D/H_F). Going again to the decay curves and using these values for H_F, it may be seen that H_D/H_F must be between about 0.285 and 0.295. Repeating the above process with these new values of H_D/H_F would again reduce the range, though this is probably not warranted as it may be seen that the desired value of H_D/H_F will be very close to 0.29. Hence the wave height at the end of a 100-mile fetch which will produce a 3-foot wave after a 500-mile decay is 3/0.29 or 10.3 feet. This point may then be plotted on the Bretschneider generation figure at the intersection of the 100-mile

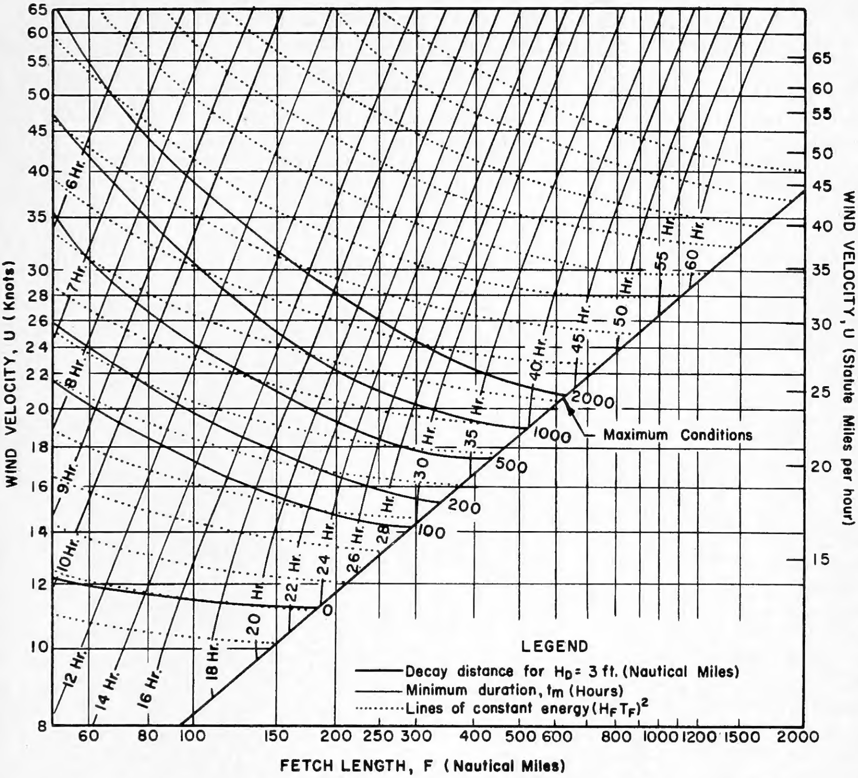

FIGURE 1 - FORCASTING CURVES FOR WAVE GENERATION (3 FT. WAVES)

fetch line with the 10.3-foot wave height line. Other points on the 500-mile decay curve may be obtained similarly and the line drawn in. The curves for other decay distances may then be derived in a like manner, and the entire family of curves plotted.

It is thought that curves such as those shown may be used to considerable advantage in determining hindcast frequencies of waves greater than a particular limiting value, representing a large time saving over previous (but more complete) methods.

A COMPARISON OF DEEP WATER WAVE FORECASTS BY THE PIERSON-NEUMANN, THE DARBYSHIRE, AND THE SVERDRUP-MUNK-BRETSCHNEIDER METHODS WITH RECORDED WAVES FOR POINT ARGUELLO, CALIFORNIA FOR 26-29 OCTOBER '50

by
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A brief comparison of deep water wave forecasts made by the Darbyshire and the Sverdrup-Munk-Bretschneider methods with recorded waves at Point Arguello, California for October 26-29, 1950 has previously been made (1,2)*. A further comparison for this same period with the method recently developed at New York University(3) is believed to be of further interest; this method is referred to herein as the Pierson-Neumann or Wave Spectra method.

This latter method differs from the Sverdrup-Munk-Bretschneider method in that:

(1) Greater cognizance is taken of the entire wave spectrum which is treated as the sum of numerous simple sine waves. In the use of the method, each simple component is treated individually, and the resultant characteristics obtained by summing up the components pertinent to the particular place and time. (The Darbyshire method also does essentially the same.)

(2) Wave decay is considered as being due entirely to dispersion (the stretching out of a wave train as the longer period, higher velocity waves pass through and beyond the shorter period waves) and to angular spreading (the spreading out of the area of wave activity due to the difference in direction of the various wave components). This latter means that fetch width is considered as an important factor in the determination of wave height after decay. For example, given two fetches, one being twice as wide as the other, the waves created by the wider fetch will be $\sqrt{2}$ higher than those of the narrower fetch. Important consideration is thus given to the angular spread of the waves as they are propagated from the fetch front to a coastal point. That is, the greater the angle between a line drawn from the same point of observation to the extreme end of the fetch front and a line extended from the fetch side, the relatively higher the waves will be at the point of observation (see Figure 1).

* Numbers in parentheses refer to References at the end of the article.

Application of the Pierson-Neumann method, as developed at New York University, to the October 1950 storm showed that the first waves generated by this storm would arrive at Point Arguello at about 1800 October 26, more or less at the same time as predicted by Bretschneider(2), and by the Darbyshire method. (See Figure 2). For the following 18 hours, the waves predicted by the "Wave Spectra Method" were considerably lower than those predicted by Bretschneider and those shown by the recorder; but were almost identical with those predicted by the Darbyshire method. During the following 48 hours, the waves predicted by the Pierson-Neumann method were considerably higher than either the recorded or those predicted by Bretschneider, averaging about twice as high as those predicted by Bretschneider; this average was taken over 6-hour intervals (see Figure 2). The peak storm waves occurred at 1200 October 27 according to both Bretschneider and the recorder and were about 14 feet in height; however, the peak waves obtained by the Pierson-Neumann method averaged about 21 feet in height and arrived 6 hours later at 1800 October 27.

An hourly average taken over the 66-hour period from 1800 October 26 to 1200 October 29, showed that the wave height determined by the Pierson-Neumann method was 10.4 feet as contrasted with 7.8 feet for Bretschneider (for a more exact comparison see Figure 2). Due to the variance in wave height between Bretschneider, Darbyshire and the recorder as against the Pierson-Neumann results, it was believed possible that errors had been made in the application of this method, and a second independent hindcast analysis was made by another Beach Erosion Board staff member. The results were about the same; the wave heights obtained by the Pierson-Neumann method again being about twice the others for the period from 1200 October 27 to 1200 October 29, and the storm peak height being about 23 feet.

There would appear to be several possible explanations for the difference between the two results. One is, of course, error in application of the newer method. Another is possible error in analysis of the observed waves -- these were obtained from a pressure recorder, and analysed by the significant wave concept, which generally gives somewhat (5 to 15 percent) lower values than actual. Still another is difficulty in using the Co-Cumulative Spectra Curves of the Pierson-Neumann method. In this connection it was often almost impossible to determine with any accuracy the frequencies, hourly durations and the corresponding energy (E) values located near the curve extremes (and frequently values determined for these regions from one set of curves would not agree with those from another). A portion of the differences in height may certainly be ascribed to this reason (i.e. difficulty in accurately reading the curves for high velocities and low durations). It is understood that these curves have now been redrawn and are in the process of publication by the Navy Hydrographic Office, so that this difficulty will no longer exist in the future.

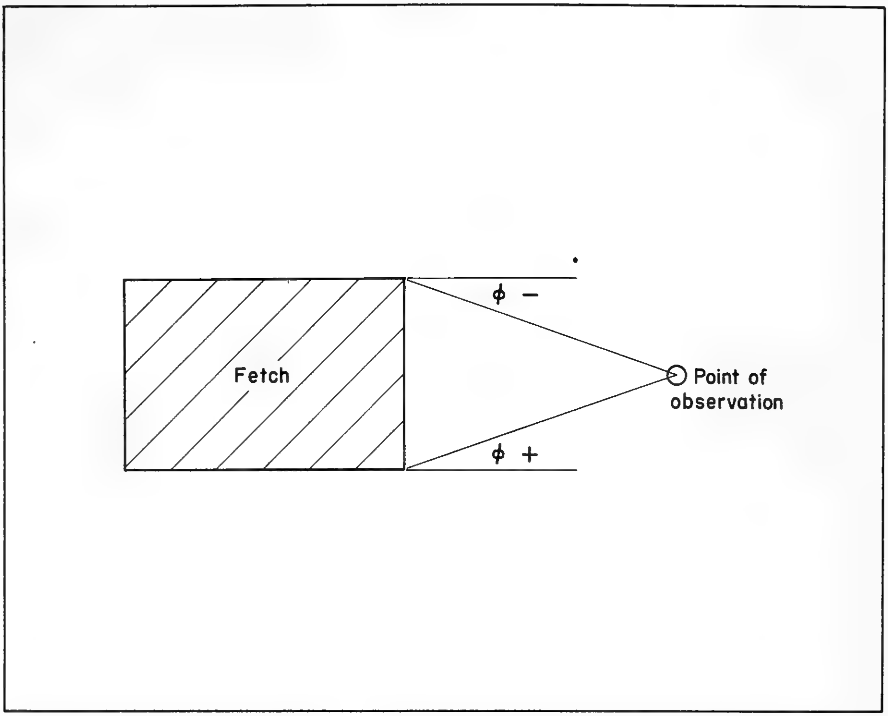


FIGURE I. CONSTRUCTION OF ϕ ANGLES FOR ANGULAR SPREADING FACTOR

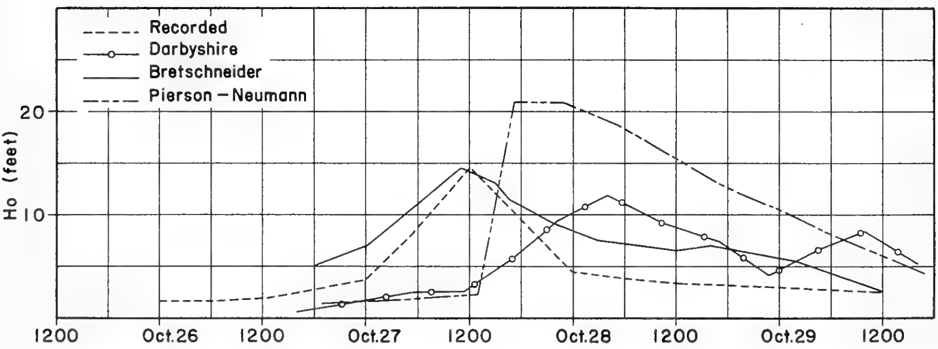


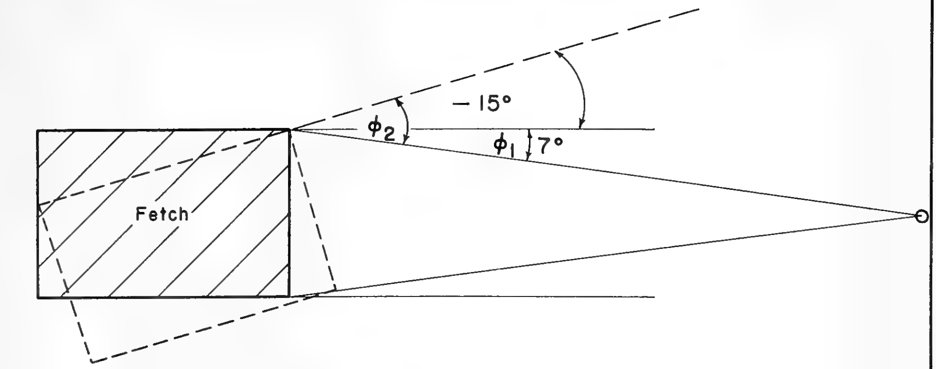
FIGURE 2. WAVE HEIGHTS PT. ARGUELLO, CALIFORNIA OCT. 26 - 29, 1950

Another major source of difference is, of course, the analysis of the meteorological situation from the data shown on the weather maps. In this case the fetch lengths, decay distances, wind velocities and durations were chosen essentially identical with those used by Bretschneider; these values have been checked and used by other authors (1,4,5) and would appear to be the best available data. However, the selection of these values is largely subjective, and other analysts might well select different values. The use of different values (as say, lower wind velocities and positioning of the front edge of the fetch closer to the indicated front - see Figure 1) while not necessarily reducing the differences between the results obtained by the two methods, would result in values obtained by the Pierson-Neumann method being much closer to the observed.

In the use of the Pierson-Neumann method an additional subjective factor enters in the determination of the fetch width. Fetch width in relation to decay distance has important significance in the Pierson-Neumann theory; that is, the greater the fetch width, the greater the wave height, all other things being equal. There is possibility of error here, in that exact determination of the fetch width is dependent on the accuracy of judgment of the user, which is to be obtained only by a great deal of experience in the use of the method and comparison with recorded values. Such experience is lacking here, and it is quite possible that a more applicable value could have been chosen.

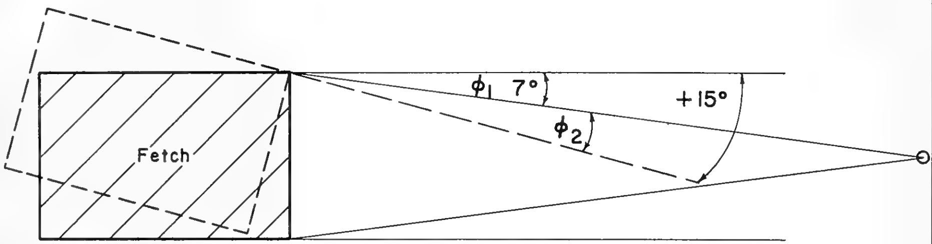
The angular spread of the waves as they are propagated from the fetch front to a point of observation is also of importance in this method. An energy correction factor for this angular spread is a function of the angles formed by drawing lines from the point of observation to the two extremes of the fetch width and extending lines from the fetch sides (see Figure 1). Assuming a true initial angle of 7°, a difference of 15° in fetch direction, in a negative (upward) direction, would result in an increase of 45 percent in wave height. Conversely, a difference of 15°, in a positive (downward) direction, would result in a decrease of 68 percent in wave height (see Figure 3). A graph depicting percentage increases and decreases in wave height for true initial angles of 7°, 12°, 22° and 32° and angular differences of 1° through 15° is shown on Figure 4.

A combination of differences in fetch width and angular spreading values may give rise to possible wave height increases of large magnitude. For example, assuming an angular negative difference (upward) of 15° in combination with a fetch width difference of 2 (twice the fetch width being used) the resultant wave height would be 1.7 times that otherwise obtained. This is based on an initial angle of 7°; for initial angles of greater degree, the wave height increase would be relatively smaller. Figure 5 illustrates the relative height increases due to an angular negative difference of 15° for initial angles of 7°, 12°, 22° and 32°. For a positive (downward) angular difference of 15°, the resultant effect upon the wave height is negligible, ranging from 0.93 to 1.12 for the same angular range as above.



ϕ_1 = true initial angle = 7°

$\phi_2 = -15° - 7° = -22°$ (erroneous initial angle due to hypothetical angular error in fetch front)



ϕ_1 = true initial angle = 7°

$\phi_2 = -7° + 15° = +8°$ (erroneous initial angle due to hypothetical angular error in fetch front)

FIGURE 3. POSSIBLE ERRORS IN CONSTRUCTION OF ϕ ANGLES

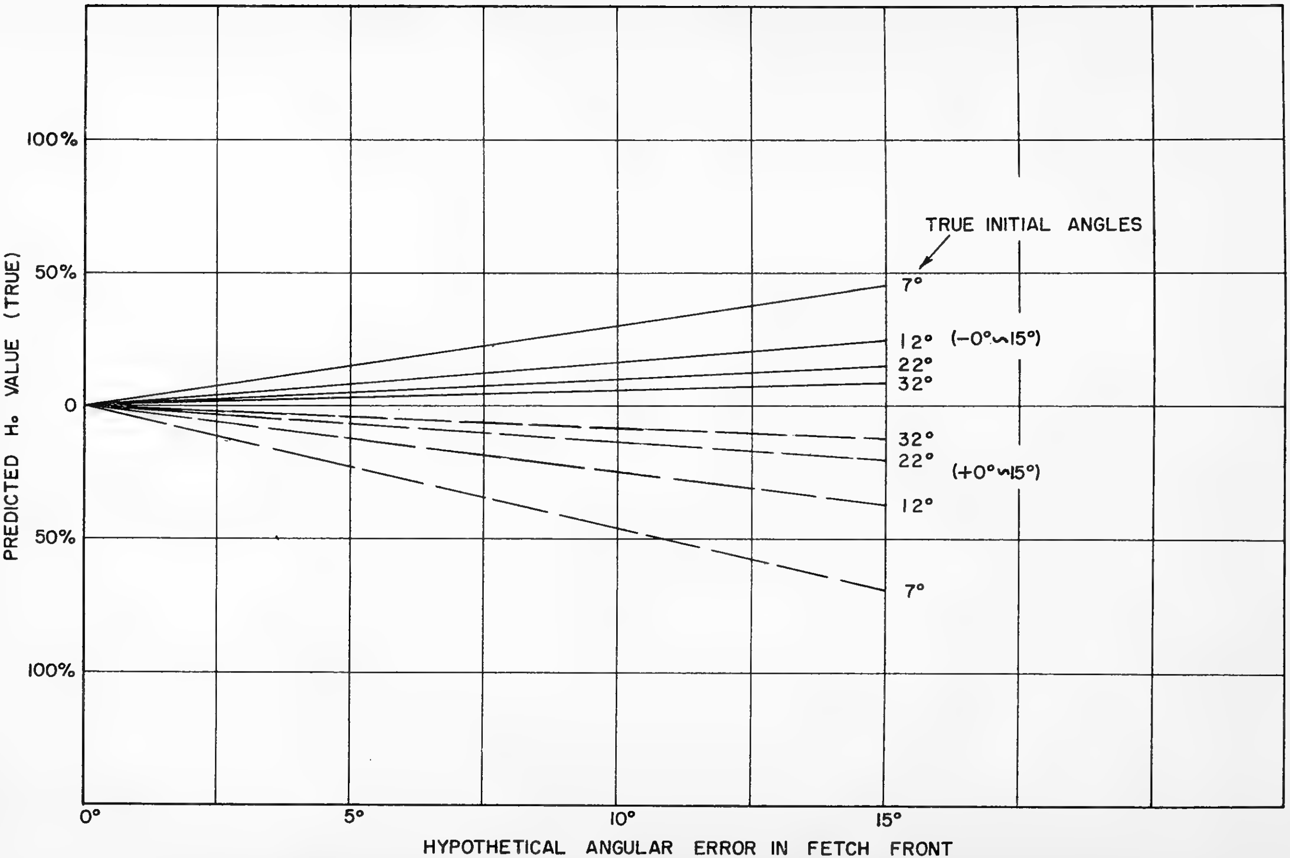


FIGURE 4 - RELATIONSHIP FOR CHANGE IN PREDICTED VALUE OF H_0 WITH ANGULAR ERROR IN FETCH FRONT

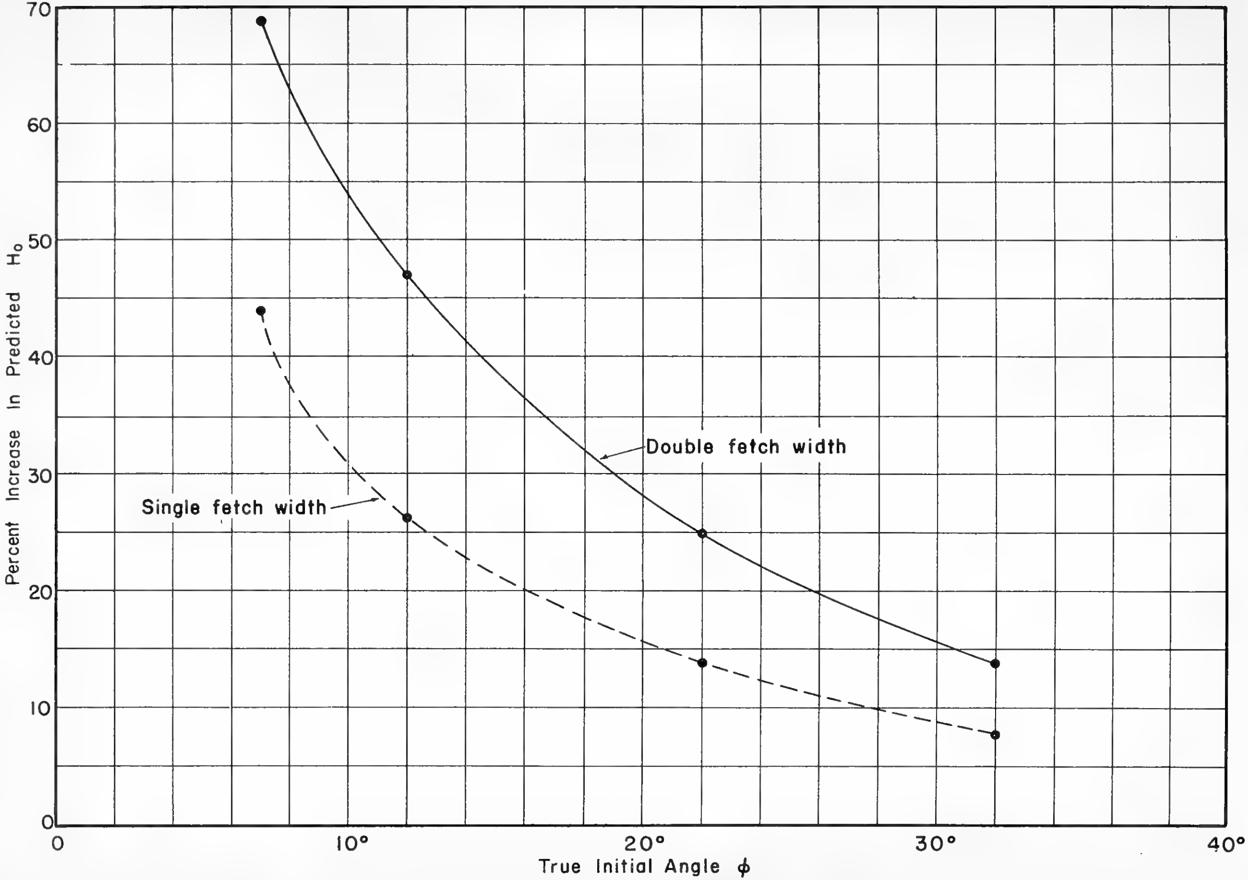
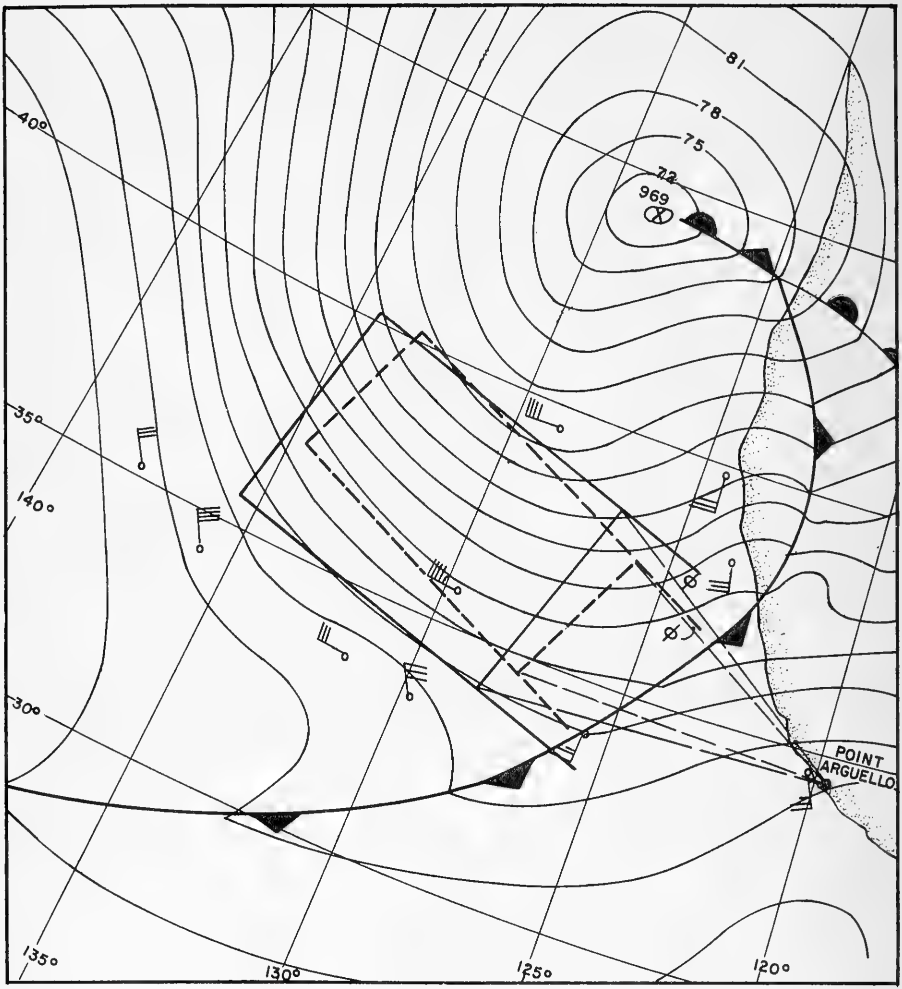


FIGURE 5. PERCENT INCREASE IN PREDICTED H_0 ASSUMING 15° ANGULAR ERROR (NEGATIVE) IN FETCH FRONT, USING BOTH SINGLE AND DOUBLE WIDTH FETCHES



Fetch As Used.
Fetch As Might Have Been Used.

FETCH CONDITIONS 0030Z 27 OCTOBER 1950
FIGURE 6

The weather situation resulting in the peak waves is shown in Figure 6; the fetch used by the author is also shown (as a solid line), delineating the fetch width and decay angles. This was also essentially the fetch determined by the second (independent) Board forecaster. Although from the weather maps, this would appear to the author (and his co-workers) to be the most accurate determination of the fetch (in view of the pictured weather situation), certainly others could be chosen. Such a fetch as shown by the dotted line, although not appearing to the author to represent as closely the weather siutation pictured, on the map, might well still be possible of selection (particularly by a forecaster more experienced in the use of this method) and would give results much closer to those observed.

In conclusion, it might be stated that the larger wave heights forecast in this one example by the Pierson-Neumann method could result from inaccurate or inapplicable determination of fetch width and angular spreading, inability to accurately interpret the Co-Cumulative Spectra Curves, difficulties inherent in the subjective choice of the applicable meteorological parameters, and lack of experience with this newer method. It should be emphasized that this paper is based on a comparison of forecast methods as applied to one storm only and is per se limited in its scope; no conclusions as to the relative accuracy of the methods can be drawn until much wider application of the newer method is made, so that some sort of statistical comparison over a long period of time (as 1 year) can be made.

REFERENCES

1. Datz, M. - Comparison of Deep Water Wave Forecasts by the Darbyshire and Bretschneider Methods and Recorded Waves for Point Arguello, Calif., 26-29 Oct 1950, Bull. Beach Erosion Board, V.7, No. 4, 1953.

2. Bretschneider, C. L. - Revised Wave Forecasting Curves and Procedure, Univ. of Calif., Inst. of Eng'g. Research, Ser. 29, no. 155-47, 1951 (unpubl.)

3. Pierson, W. J., Jr., G. Neumann, and R. W. James - Tech. Rpt. No. 1 (prepared for project AROWA) N.Y.U. College of Eng'g., Res. Div. "Practical Methods for Observing and Forecasting Ocean Waves by Means of Wave Spectra and Statistics".

4. Kaplan, K. - Analysis of Moving Fetches for Wave Forecasting, Beach Erosion Board Tech. Memo. No.35, 1953.

5. Beach Erosion Board - Shore Protection Planning and Design, Beach Erosion Tech. Report No. 4, 1954.

STATUS OF SAND BY-PASSING PLANT AT SALINA CRUZ HARBOR, ISTHMUS OF TEHUANTEPEC, MEXICO

Details of the Salina Cruz stationary by-passing plant were presented in two previous Beach Erosion Board Bulletins. An article in the July 1951 Bulletin described the completed installation and pointed out the difficulties in creating a natural flow of sand into the reaches of the suction lines of the pumps. An article in the April 1952 Bulletin reviewed the functional aspects of the installation, including some characteristics of the beach in the vicinity of the harbor. The 1952 article pointed out that creating a natural flow of sand to the pump intake had not been satisfactorily accomplished as of that date.

The report herein covers the general progress of the Salina Cruz by-passing plant since 1952, as outlined in a September 1954 letter received from the Director, Mexican Free Ports. Figure 1 shows the Port of Salina Cruz, which is located on the Pacific Coast of Southern Mexico. The Port is divided into an inner and outer harbor with the by-passing plant located adjacent to the west breakwater of the outer harbor. The basic intent of operation of the by-passing plant was to intercept the eastward drifting sand and pump it through a discharge line extending over the loading docks and a swing span separating the two harbors, thence, to the shore east of the east breakwater. The intakes for the pumps were located landward of the high water line and attempts were made to create a movement of sand to the suction lines by means of a dragline and other equipment. These attempts to feed the sand to the point of pump intake, with the intention of causing recession of the shore line, have been discontinued since the procedure has proven to be inefficient and very costly. Another factor which caused the temporary discontinuation of the sand by-passing operation was the frequent interruption of pumping necessary for opening the discharge pipe swing span to allow all types of craft to enter or leave the inner harbor. This resulted in a negligible quantity of sand being by-passed.

Since the discontinuation of operations, the harbor has shoaled at a more rapid rate. At the beginning of 1954 it was necessary to use two hopper dredges, the "Presidente Aleman" and the "Coatzacoalocs" in order to maintain the harbor.

A program has been undertaken to reduce shoaling in the harbor and reactivate the by-passing plant. The program consists of building a rubble mound groin normal to the beach (as indicated in Figure 1), about 2,000 feet west of the dredge installation. The present length of the groin is about 260 feet, and its final length will be approximately 560 feet. The purpose of this groin is to reduce the supply of sand

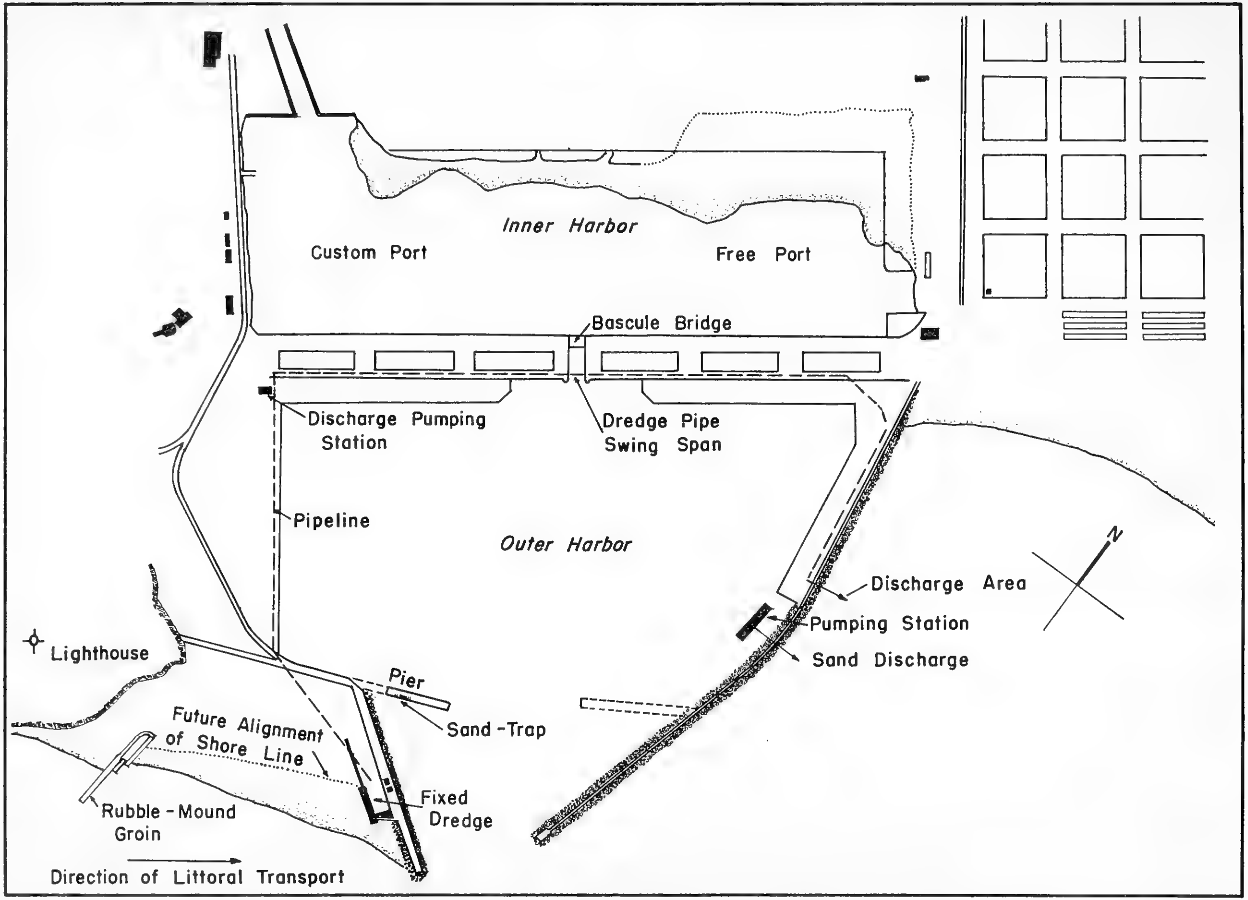


FIGURE I. OPERATION OF FIXED DREDGE AT SALINA CRUZ, MEXICO

to the beach between the groin and the stationary by-passing plant, with the expectation that this reduction in supply will cause this shore line to recede to the desired design alignment. The initial behavior of the groin is as designed, even though it has not been constructed to its final length. It was anticipated that the sand eroded from between the groin and by-passing plant would be transported into the harbor and this condition is being resolved by having a hopper dredge operate within the outer harbor.

It is expected that when the groin has been constructed to its design length, and its impounding capacity has been reached, the beach to the east of the groin will have eroded sufficiently to enable the stationary by-passing plant to operate directly offshore as originally designed.

To overcome the problem of pumping interruption occurring when the pipe swing span is opened, an impermeable pier is planned on the harbor side of the west breakwater. This structure is designed to serve two purposes, first, as a sand trap to prevent any further shoaling of the outer harbor and, second, as a mooring place for hopper barges which will receive the sand pumped by the stationary dredge. The hopper barges will then be towed across the harbor where they will be emptied by means of a pumping plant located on the eastern breakwater, and the sand will be deposited on the beach east of the breakwater.

PROGRESS REPORTS ON RESEARCH SPONSORED BY THE BEACH EROSION BOARD

Abstracts from progress reports on several research contracts in force between universities or other institutions and the Beach Erosion Board, together with brief statements as to the status of research projects being prosecuted in the laboratory of the Beach Erosion Board are presented as follows:

I. University of California, Contract No. DA-49-005-eng-8, Status Report No. 16, 1 July through 30 September 1954.

Good progress was made on the statistical compilation of the data for the sand samples collected around the rocky promontories in Southern California. This compilation is now 90 percent completed.

In September a voyage was made in cooperation with Scripps Institution of Oceanography using the vessel E. R. SCRIPPS, to take underwater photographs of the sediments off Point Dume, and the southern side of Catalina Island. A good selection of photographs was obtained by aqualung divers, the divers being trained scientists who made detailed observations of the sea bottom in conjunction with the photographs. A well defined series of ripple marks were present upon the sea bottom in this area, their axes being essentially parallel to the front of the waves approaching the coast. In one place transverse sand waves with amplitudes of 6 to 7 feet and heights of nearly 1 foot were observed just outside the breaker zone. The axis of these ripples was essentially at right angles to the coast line.

II. University of California , Contract No. DA-49-005-eng-17, Status Reports 4,5 and 6, 1 January to 30 September 1954.

Experimental work on the various stages of ripple formations until their final disappearance was continued using materials of different sizes and density. Analyses indicate that steepness of the ripples during these stages can be described as a function of a dimensionless parameter involving the maximum velocity, density, and size of the particles, and the kinematic viscosity of the fluid in which the motion takes place. The function can also be used to define the initial and general movements and also the initiation and the final disappearance of the ripples.

III. University of California, Contract No. DA-49-005-eng-31, Status Report No. 5 (Final) 1 August - 1 October 1954.

Three reports dealing with water surface roughness and shear stress, and wind waves and set-up in shallow water were in preparation.

IV. University of California, Contract No. DA-49-055-eng-44, Status Report No. 1, 1 July through 30 September 1954.

Laboratory studies of wave refraction are to be made, this study being an extension of a prior study where wave refraction on a beach of 1:40 slope with beach orientations of 15, 34, and 50 degrees with respect to the direction of the generated wave train, was studied in an effort to evaluate the usefulness of Snell's Law. The present study uses the same beach orientations, but the slope of the beach is varied; 1:20, 1:40, and 1:60 slopes are used. The ripple tank four feet wide, twenty feet long and five inches deep has had a glass plate 45" x 72" x 3/8" installed in the middle of the tank bottom for these experiments.

Large scale studies of wave refraction using a 150' x 60' x $2\frac{1}{2}$' model basin with a built in beach and a flapper type wave generator are planned. Large scale comparisons with model results will be made using a slope of 1:40 and beach orientations of 15 and 50 degrees. The beach in the large basin will also be modified to allow waves to continue over the beach into a constant depth of water ($d/L = 0.1$); hence, they will not break on the beach. In this case slopes of 1:20, 1:40 and 1:60, and beach orientations varying from 5 to 85 degrees, if possible, will again be used.

V. Scripps Institution of Oceanography, Contract No. DA-49-055-eng-3, Quarterly Progress Report No. 21, July-September 1954

Periodic measurements of sand-level changes with reference rods have now extended over a period of 18 months. The maximum change during the entire period now stands at 0.18, 0.21, and 0.07 ft. in areas where the water depth is approximately 30, 52, 70 feet respectively.

Results of the quarterly survey of the valley heads of Scripps Submarine Canyon seem to indicate a considerable shoaling of the valleys and some shoaling of the ridges between them. Divers reported that instruments placed on the canyon bottom are being rapidly covered by kelp and sand.

VI. The Agricultural and Mechanical College of Texas, A & M Project 95, Quarterly Report for period ending 14 September 1954.

This project consists of preparation of Statistical Wave Data on the United States shore of the Gulf of Mexico obtained by hindcast methods.

This period was devoted to organization and to training of project personnel, including personnel for construction of refraction diagrams for various areas of the Gulf Shelf and computation of generation of wind waves over a shallow bottom of variable slope. A simple and yet accurate method of hindcasting wind waves over a shallow continental slope is being investigated.

VII. Waterways Experiment Station, Vicksburg, Mississippi

Wave Run-up Study:

Testing was resumed on the 1 on $1\frac{1}{2}$ slope step-face wall, and these tests were completed. Testing was initiated on a recurved wall.

VIII. Beach Erosion Board, Research Division, Project Status Report for Quarter ending 15 December 1954.

In addition to the research projects under contract to various institutions which are reported on above, the Research Division of the Beach Erosion Board is carrying out certain projects with its own facilities. The main unclassified projects have been described in previous numbers of the Bulletin, and a short description of some of the work accomplished through the last quarter is given below.

The Study of The Reforming of Waves After Breaking - Beach bar slopes of 1:90, 1:60, 1:30, and 1:10 with varying depths over the bar have been tested and the data is now being analysed.

Study of Sand By-Passing Operation at Port Hueneme - Data taken before, during and after the Port Hueneme dredging project is being reviewed, organized, and analysed. It is hoped that a hydrographic survey may be obtained in the near future to serve as a 6 month comparison.

Routine progress, testing and analysis have been made on the other projects being carried out by the Research Division. In addition, Research Division reports on "Laboratory Study of Equilibrium Profiles of Beaches" by R. L. Rector and "Laboratory Study of Effect of Varying Wave Periods on Beach Profiles" by G. M. Watts, were completed and published as Technical Memorandums No. 41 and 53. Also reports resulting from contract investigations made for the Beach Erosion Board were published as follows: "Modification of Wave Height Due to Bottom Friction, Percolation and Refraction" by C. L. Bretschneider and R. O. Reid; "Field Investigation of Wave Energy Loss in Shallow Water Ocean Waves" by C. L. Bretschneider; "Statistical Significance of Beach Sampling Methods" by W. C. Krumbein; "Generation of Wind Waves over a Shallow Bottom", by C. L. Bretschneider; and "Theory of the Ocean Wave Spectrum and Its Uses in Wave Train Analysis", by W. J. Pierson, were published as Technical Memorandums No. 45, 46, 50, 51 and 56 respectively.

Also a 4-week work conference of representatives of various Corps of Engineers Offices was held at the Beach Erosion Board to analyse data on waves in inland reservoirs. A rough draft report was completed, showing that the S.M.B (Sverdrup-Munk-Bretschneider) curves agree very closely with observed results if proper corrections are made for fetch width and the difference in velocity between over-water and over-land winds.

BEACH EROSION STUDIES

Beach erosion control studies of specific localities are usually made by the Corps of Engineers in cooperation with appropriate agencies of the various States by authority of Section 2 of the River and Harbor Act approved 3 July 1930. By executive ruling the costs of these studies are divided equally between the United States and the cooperating agencies. Information concerning the initiation of a cooperative study may be obtained from any District or Division Engineer of the Corps of Engineers. A list of authorized cooperative studies follows:

AUTHORIZED COOPERATIVE BEACH EROSION STUDIES

MASSACHUSETTS

PEMBERTON POINT TO GURNET POINT. Cooperating Agency: Department of Public Works.

Problem: To determine the most suitable methods of shore protection, prevention of further erosion and improvement of beaches, and specifically to develop plans for protection of Crescent Beach, the Glades, North Scituate Beach and Brant Rock.

CHATHAM. Cooperating Agency: Department of Public Works.

Problem: To determine the best method of preventing shoaling of Stage Harbor and damage to shore property, and the effects on Stage Harbor and adjacent shore property of probable changes to Nauset Beach and Monomoy Island and any works which may be constructed for protection of Stage Harbor.

CONNECTICUT

STATE OF CONNECTICUT. Cooperating Agency: State of Connecticut (Acting through the Flood Control and Water Policy Commission)

Problem: To determine the most suitable methods of stabilizing and improving the shore line. Sections of the coast are being studied in order of priority as requested by the cooperating agency until the entire coast has been included.

NEW YORK

N. Y. STATE PARKS ON LAKE ONTARIO. Cooperating Agency: Department of Conservation, Division of Parks.

Problem: To determine the best method of providing and maintaining certain beaches and preventing further erosion of the shore at the Braddock Bay area owned by the State of New York

FIRE ISLAND INLET AND VICINITY: Cooperating Agency: Long Island State Park Commission

Problem: To determine the most practicable and economic method of providing adequate material to maintain the shore in a suitably stable condition and an adequate navigation channel at Fire Island Inlet.

SUFFOLK COUNTY (ATLANTIC COAST BETWEEN MONTAUK POINT AND FIRE ISLAND INLET). Cooperating Agency: Department of Public Works, State of New York.

Problem: To determine the most practicable and economic method of restoring adequate recreational and protective beaches and providing continued stability to the shores.

NEW JERSEY

STATE OF NEW JERSEY. Cooperating Agency: Department of Conservation and Economic Development.

Problem: To determine the best method of preventing further erosion and stabilizing and restoring the beaches, to recommend remedial measures, and to formulate a comprehensive plan for beach preservation or coastal protection. The current study covers the shore from Barnegat Inlet to Cape May.

DELAWARE

STATE OF DELAWARE. Cooperating Agency: State Highway Department

Problem: To formulate a comprehensive plan for restoration of adequate protective and recreational beaches and a program for providing continued stability of the shores from Kits Hummock on Delaware Bay to Fenwick Island on the Atlantic Ocean.

NORTH CAROLINA

CAROLINA BEACH. Cooperating Agency: Town of Carolina Beach.

Problem: To determine the best method of preventing erosion of the beach.

CALIFORNIA

STATE OF CALIFORNIA. Cooperating Agency: Department of Public Works, Division of Water Resources, State of California

Problem: To conduct a study of the problems of beach erosion and shore protection along the entire coast of California. The current studies cover the Santa Cruz, Orange County and San Diego Areas.

WISCONSIN

MANITOWOC-TWO RIVERS. Cooperating Agencies: Wisconsin State Highway Commission, Cities of Manitowoc and Two Rivers

Problem: To determine the best method of shore protection and erosion control.

MICHIGAN

BERRIEN COUNTY. Cooperating Agency: City of St. Joseph

Problem: To determine the most effective methods of preventing erosion of the shore by waves and currents.

TERRITORY OF HAWAII

WAIMEA & HANAPEPE, KAUAI. Cooperating Agency: Board of Harbor Commissioners, Territory of Hawaii.

Problem: To determine the most suitable method of preventing erosion and of increasing the usable recreational beach area, and to determine the extent of Federal aid in effecting the desired improvement.